Ear Nose Throat Anatomy

Introduction

We've spent much of the pulmonary module on the airway below the larynx, the trachea to the alveoli. That is the "lower" respiratory tract. The "upper" respiratory tract is everything above the larynx. It includes the nasal cavity, eustachian tubes (the middle ear), and the sinuses, as well as the oropharynx and nasopharynx. The trachea is derived from endoderm, from the gut tube. The trachea has respiratory epithelium—pseudostratified ciliated columnar cells with goblet cells. The gut tube has esophageal epithelium—nonkeratinized stratified squamous epithelium. The pharynx serves both to bring air to the lower airway and to bring food to the esophagus. The pharynx is derived from the gut tube. Whereas the trachea began as an appendage to the gut tube, so is the rest of the upper airway an appendage of the pharynx. The eustachian tubes and nasal cavity are respiratory organs lined with respiratory epithelium, just like the trachea. They are vulnerable to the same infections, and those infections are different than the ones that have tropism for the pharyngeal epithelium.

This lesson is going to be the normal ENT. The primary focus is going to be on the nasal cavity and sinuses because we already touched on the oropharynx in Gastroenterology. The goal is to establish a solid foundation of anatomy and histology, drawing on what you already know from the lower airway in terms of physiology. Because the larynx is quite complicated, in three dimensions and in a small space, we spend a lot of time on it at the end. This will provide the necessary foundation for the infections and malignancies that round out the pulmonary module in the next lesson.

Perspective—Nasal Cavity

The nasal cavity is very difficult to represent simply because it is made of so many bones. They approach from all directions. It helps to recognize that the nasal cavity isn't a thing, but rather the absence of things. It is the space left over by the articulation of multiple bones. Each bone does something— protects the brain, forms your cheeks, supports the bridge of the external nose. These bones come together and fuse. The space left over is just that—space. The nasal cavity and sinuses are air-filled caverns formed by bone and lined with respiratory epithelium. We're going to try to build up a visual representation of these structures, starting with the bones and cartilage.

Bones and Cartilage—Nasal Cavity

The bones of the skull that do *not* participate in the formation of the nasal cavity are the zygomatic bone (outside, bottom of the orbit), the mandible (the jaw), the temporal bone (side of the head), and the occipital bone (back of the head). They are named and depicted in Figure 1.1 so you can better identify the ones that do. Our brain is protected by the skull. This is true. But part of our brain—the olfactory bulb in the nasal cavity and our eyes in their sockets—exists outside the protection of the skull. That means that the frontal bone may be the front of the head, but it isn't the entirety of the anterior protection for the brain.

The orbit of the eye encases all except the most anterior part of the squishy eyeball. That is covered by an eyelid. The eyeball is fairly large. A gaping hole in the skull as big as the eyeball isn't a good idea—that would leave the brain unprotected. So there are bones around and behind the eyeball that protect the brain in case something came through the eyeball. The lateral bones of the orbit are nowhere near the nasal cavity. But the medial bones and the floor of the orbit are the same bones that make the lateral side and top of the nasal cavity.

The **top** of the nasal cavity is made up of, anterior to posterior, the **ethmoid bones** and the **sphenoid bone**. The **floor** of the nasal cavity is the **palatine bone**. The **sides** are a combination of the **lacrimal**, **maxillary**, ethmoid, and sphenoid bones. The **front** of the nasal cavity is the bone of the bridge of the external nose, the **nasal bone.**
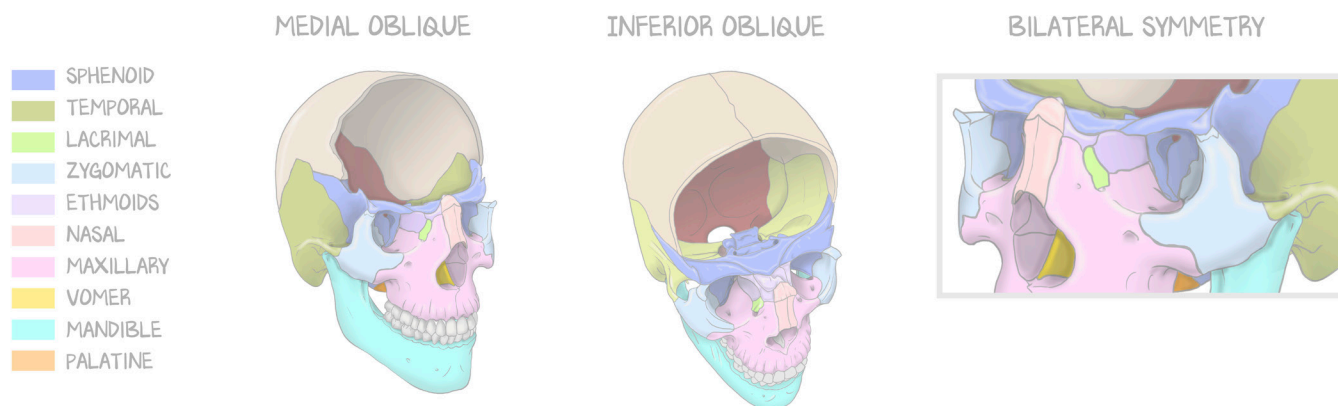

MEDIAL OBLIQUE   INFERIOR OBLIQUE   BILATERAL SYMMETRY

- SPHENOID
- TEMPORAL
- LACRIMAL
- ZYGOMATIC
- ETHMOIDS
- NASAL
- MAXILLARY
- VOMER
- MANDIBLE
- PALATINE

Figure 1.1: Bones of the Face
The bones of the face that do *not* participate in the formation of the nasal cavity are the temporal, zygomatic, and occipital bones and the mandible. Those that *do* are tough to see with just one perspective. This illustration gives you two perspectives and one at a higher magnification so you can see the interactions of the bones. You don't have to memorize this or be able to reproduce it. This illustration is only to enhance comprehension. The oblique views make things easier to see than most two-dimensional illustrations drawn at sharp angles.

Dividing the nasal cavity into right and left is the **septum**. The portion of the septum within the external nose is **septal cartilage**, and the portion deep within the nasal cavity is the **ethmoid bone**.

Cartilage is used in several places, all of which are in the external nose, the part that is exposed to the environment. Cartilage is softer than bone and allows for deformation of the nose when it suffers impact—cartilage bends, whereas bone breaks. The **septal cartilage** runs along most of the septum except for in back and high up, where the olfactory bulb is (which is protected by the ethmoid bone). The **lateral alar cartilage** lines the top of your nose, the **major alar cartilage** is the bottom of the external nose, and the **minor alar cartilage** is the side of the external nose.
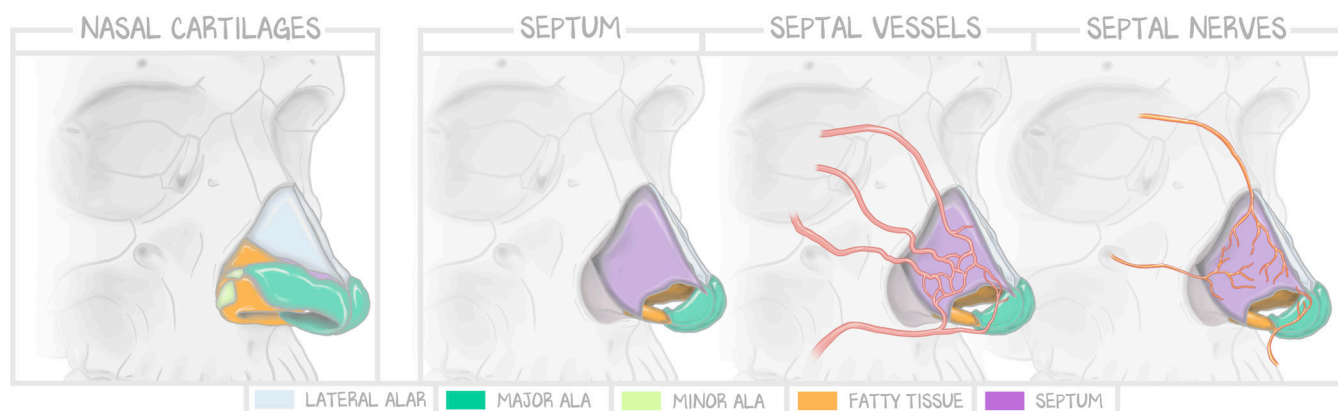

NASAL CARTILAGES   SEPTUM   SEPTAL VESSELS   SEPTAL NERVES

LATERAL ALAR   MAJOR ALA   MINOR ALA   FATTY TISSUE   SEPTUM

Figure 1.2: Cartilage of the Nasal Cavity
A visual representation of the preceding paragraph, showing the cartilages as they relate to the nasal cavity and the complete face. With the cartilage removed, you can visualize the septal and septal vessels (Kiesselbach's plexus). The origination of the nerves and arteries is purposely left out of the illustration. The fact that there is a major anastomosis in the septal cartilage is the point, not where the arteries come from.

The cartilaginous septum is highly vascularized, irrigated by no fewer than five arteries. The specific names of those arteries are not important, but the anastomosis they make is. **Kiesselbach's plexus** is the anastomosis found in the anterior septum, where the cartilage is. This is the thing responsible for **epistaxis**, nosebleeds. An **anterior nosebleed** is bleeding of this anastomosis. To stop the bleeding, lean your head forward and pinch the bridge of your nose. Leaning backward drains blood into your esophagus, may irritate the trachea and cause you to cough, and doesn't help stop the bleeding. The bleeding is from the front of the nose; let it come out the front of the nose.

Medial Septum, Lateral Turbinates—Nasal Cavity

The objective of the conducting airway is to clean and warm the air for the alveoli. The nasal cavity without the turbinates is quite a gaping chasm. Because the epithelium makes the mucus that traps the debris, that epithelium does no good being on the outside rim of a gaping chasm. Therefore, the **turbinates**, which are epithelium-lined **bony projections** of the bones that make up the lateral wall of the nasal cavity, serve to increase the amount of the cavity's space that is in contact with the epithelium. Because the medial septum is made of cartilage, it is the lateral side of the cavity that forms the turbinates. The turbinates also allow the control and flow of sinus secretions. It would be rather inconvenient if every sinus drained into a hollow tube in the center of our face that allowed mucus and debris to fall out the front of our nose . . . all the time. So, the turbinates allow more air to be cleaned, provide more surface area to warm air as it enters, reduce the volume of free space in the nasal cavity, and direct secretions toward the pharynx so they can be swallowed or expectorated.
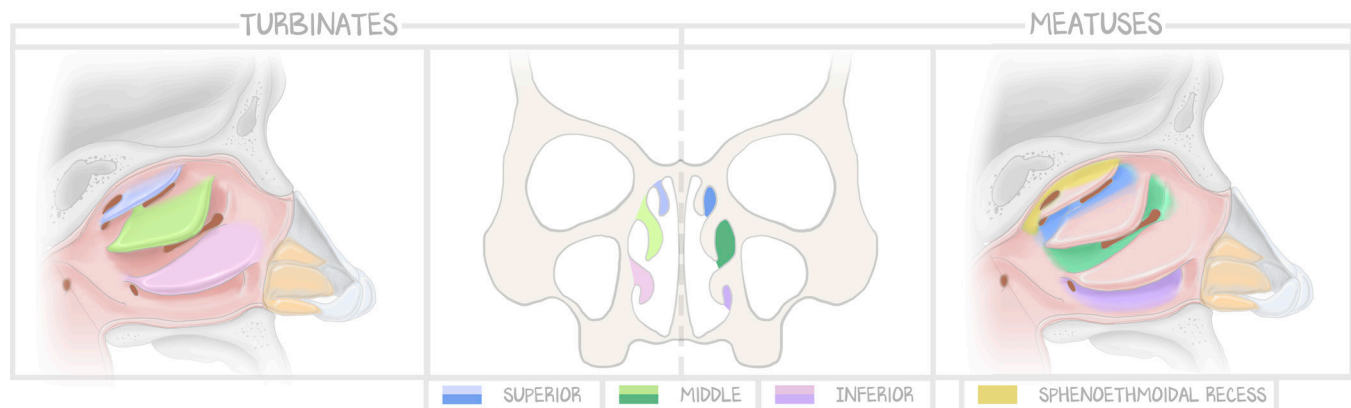

Figure 1.3: Turbinates and Meatuses
There are three turbinates—superior, middle, and inferior—on each side of the nasal cavity. They are bony projections into the nasal cavity that are covered with respiratory mucosa. The remaining septum is divided into four regions of airflow—the superior, middle, and inferior meatuses and the sphenoethmoidal recess.

Between the turbinates are meatuses, spaces through which the paranasal sinuses drain. The **superior meatus** is inferior to the superior turbinate, **the middle meatus** inferior to the middle turbinate, and the **inferior meatus** inferior to the inferior turbinate. The area superior to the superior turbinate is where the olfactory epithelium is located. We'll talk olfaction in Neuroscience: Special Senses #5: *The Nose: Olfaction*.

Paranasal Sinuses—Nasal Cavity

The paranasal sinuses are extensions of the respiratory region of the nasal cavity and are lined with respiratory epithelium. They are air-containing regions named for the bone in which they are found. They serve a purpose in the resonance of speech, but they are really there to act as crumple zones. Without the paranasal sinuses, if a facial bone were to fracture, the jagged edges could be sent into the brain that those bones are supposed to protect. But the redundancy of the frontal and sphenoid bones, coupled with the sinuses as actual spaces that bone can break into, protects the brain from damage. They are aerated, but aren't meant to be doing any of the cleaning or warming of air—they are detours away from the air tube. They also make our head less heavy, so our neck doesn't break when we jump (air is less dense than the bone around it). The problem is that they have very narrow drains into the nasal cavity, which can become plugged up, causing sinusitis (as we will discuss in the next lesson).

The **maxillary sinus** is within the maxilla. It is the most inferior of the sinuses. However, the drainage of the maxillary sinus is not to the most inferior meatus. It was originally designed for four-legged creatures, so we upright mammals must wait for the maxillary sinus to fill before it drains through the **medial meatus**. We can facilitate its drainage by lying down (or by doing a handstand), so on a day-to-day basis, this isn't a problem. But it also explains why the maxillary sinus is the sinus most likely to be infected—fluid stagnation in any hollow cavity predisposes it for bacterial infection. The **frontal sinus** is in the frontal bone. It is high up and away from the nasal cavity and drains through the **superior meatus**. The **sphenoid sinus** drains into the region above and behind the superior turbinate. The **ethmoid air cells** drain through the medial and superior meatuses. The only structure that drains into the inferior turbinate is the **nasolacrimal duct**, draining tears from the eyes.

These sinuses secrete only a small amount of fluid, so normally drain to the nasopharynx. When we cry or have increased secretions due to an infection, our nose runs because the volume of secretion exceeds the normal mechanisms of removal.
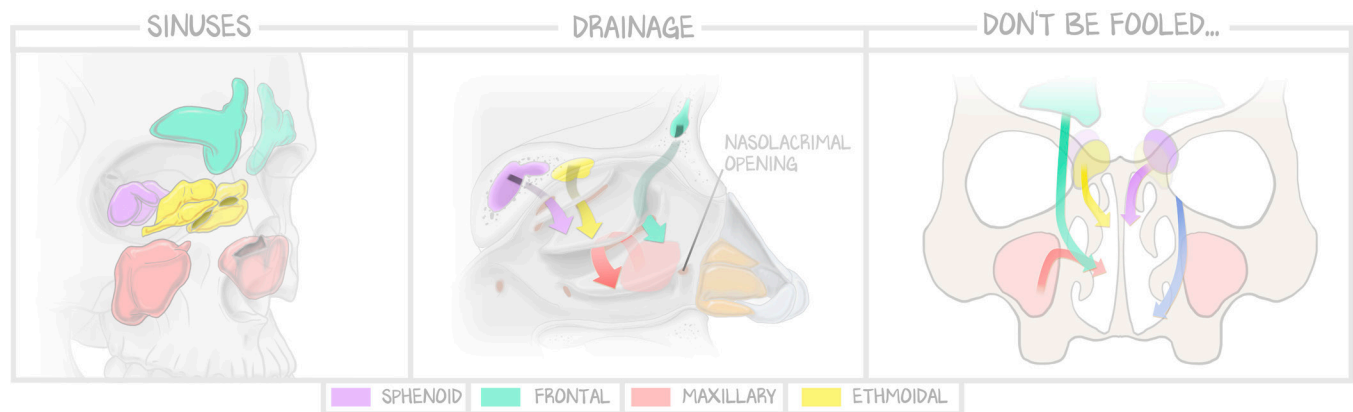

Figure 1.4: Paranasal Sinuses and their Drainage
The sinuses are air spaces within bone that are lined with respiratory epithelium. Each one drains through a meatus in the nasal cavity. The only structure that drains through the inferior meatus is the nasolacrimal duct, which carries tears from the eyes. As air moves deeper into the airway, secretions from the sinuses are swept with it. There are not four meatuses that correspond to four sinuses. There are four sinuses that drain into the nasal cavity, as does the nasolacrimal duct.

Epithelium—Nasal Cavity

The nasopharynx is the first part of the conducting airway. Normal, quiet respiration involves the use of the nose only: air moves from the nose to the back of the throat and into the trachea. The nasal cavity is therefore, unsurprisingly, lined with **respiratory epithelium**—pseudostratified ciliated columnar, goblet cells, basal cells—just like the trachea is. The sinuses drain into the nasal cavity. The **sinuses** are lined with **respiratory epithelium**. The respiratory epithelium of the nasal cavity warms, moistens, and cleans air for the alveoli. The sinuses produce mucus to trap particles and use the ciliated cells of the epithelium to sweep that trapped debris-in-mucus toward the exit, to be expectorated. The sinuses are used for phonation. Their mucous secretions and ciliary sweeping are to get any debris that gets into the sinuses out of the sinuses. Being respiratory epithelium and intimately associated with the nasopharynx, it should come as no surprise that these structures are embryologically **endoderm**.

Comparatively, the skin comes from **ectoderm**. A small bit of skin enters the nares. The external nose, the thing lined with cartilage you can put your finger on, is lined with skin. The hairs you can see when you look up your nose and the surfaces you can reach with your finger when you pick your nose are skin. The skin—strata basale, spinosum, granulosum, and corneum with skin appendages called hair—transitions to mucosa where the bony part of the nose begins. The hair appendages **prevent large organisms** (like insects) from getting into the nasal cavity. The nasal cavity and the rest of the conducting airways prevent **debris and microscopic organisms** from getting to the alveoli.
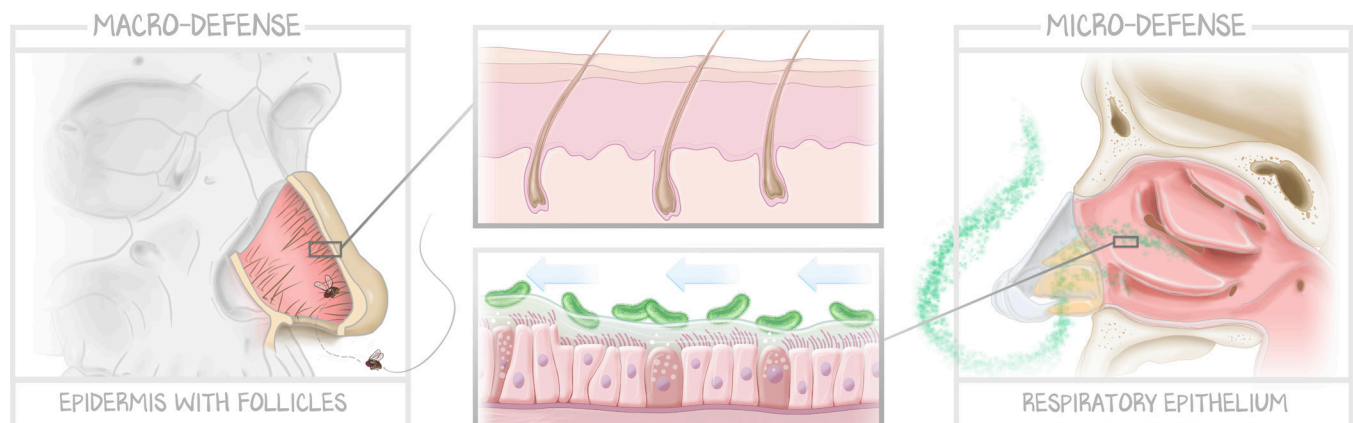

Figure 1.5: Nasal Epithelia
The exterior nasal cavity—what you consider your nose and is made of cartilage—is lined with ectoderm-derived, hair-bearing stratified squamous epithelium. This prevents the entrance of large organisms into the respiratory tract. The interior nasal cavity—made of bone—is lined with respiratory epithelium. This serves to begin stripping the air of debris and organisms that are too small to be screened out by the hair of the exterior nasal cavity epithelium.

Ear

The eustachian tube of the ear is connected to the **nasopharynx**. Yes, there is a tube that connects your ear to your throat. The eustachian tube (or **auditory tube**) is derived from endoderm, from the gut tube. The nasopharynx is squamous cell epithelium. Every appendage that involves air is respiratory epithelium. The purpose of the auditory tube has nothing to do with hearing at all. It serves to **vent the middle ear** and equalize its pressure to the atmospheric pressure. The walls of the auditory canal are usually **closed at rest**, opening only upon yawning and swallowing. That's why, by the way, yawning helps "pop" your ears when descending during a flight. It's also why you are able to plug your nose, close your mouth, and blow really hard to "pop" them (just make sure to breathe quickly after releasing so the

pressure equalizes). When you study the ear from the ear's perspective, there is an outer ear, middle ear, and inner ear. Sound travels into the auditory canal, resonates on the tympanic membrane, and transmits sounds through bones in the middle ear, which then send the sound to the cochlea of the inner ear. Most people know this before they come to medical school, but think about it on a cellular level.

The **outer ear** is derived from **ectoderm,** and so is the **skin**—keratinized squamous cell epithelium. That epithelium is separated by a translucent-but-intact tympanic membrane. The other side of that membrane is derived from **endoderm—respiratory epithelium**. The middle ear is lined with the epithelium of the auditory tube that happens to end with some bones that transmit sound. The cochlea sends **nerves** through the skull to the brain. The cochlea is **inside bone**, not surrounded by an epithelium. The middle ear, the thing that is all connected together, is the auditory tube in which the bones of the middle ear are located. The middle ear is **upper respiratory airway** that happens to have some bones in it. That's why, in pharyngitis, when you swallow, you feel razor blades in the back of your throat and sometimes pain in your ear. That's why the infections that cause sinusitis are the same organisms that cause otitis media—everything is connected, and those organisms share tropism for the same epithelium.

Audition and balance are covered in Neuroscience. The reason that ears were included in this lesson is that the specialty is otolaryngology, better known as ENT (ears, nose, throat). ENTs place ear tubes, do nose jobs, and work on the larynx. Why? It isn't because it pays well (although nose jobs do pay well), it is because they are accessing the same cells and epithelium even though the ears, nose, and throat are geographically distinct. It isn't a random assortment of organs that can be operated on; it is an accumulation of the organs that utilize the respiratory epithelium above the trachea (Pulmonology does lower airway, ENT does upper).
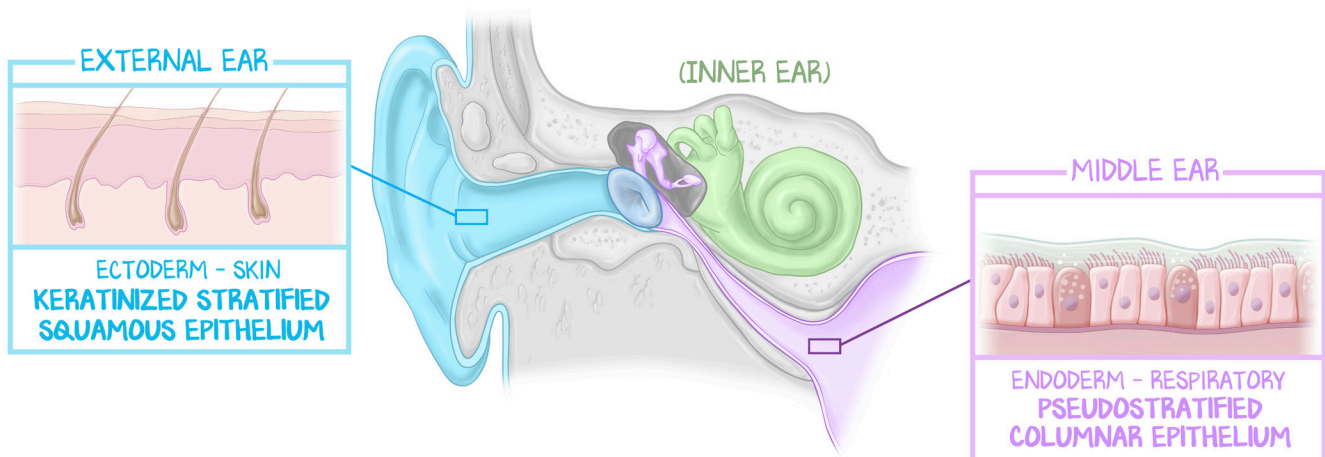

Figure 1.6: The Epithelia of the Ear
The middle ear is lined with respiratory epithelium and derived from endoderm. The "middle ear" is actually just more of the conducting airway you've been studying. It just so happens that there is a bone at the end of the auditory tube that is involved in transmitting sound. And it just so happens that the membrane that generates that sound is the boundary between the endoderm-derived respiratory epithelium and the ectoderm-derived skin of the outer ear's auditory canal. Outer ear? Hair-bearing skin. Middle ear? Respiratory epithelium. Inner Ear? Bones and nerves.

Oropharynx, Pharynx, and Larynx

The nasopharynx is the cavity and gut epithelium **above the palatine bone**. The oropharynx was discussed in GI, and is the cavity and gut epithelium from the palatine bone to the epiglottis. The **hypopharynx** is the esophagus and the **larynx**. The larynx leads to the trachea. We're in the Pulmonary module. What we care about is the respiratory stuff, specifically the larynx.

Larynx anatomy is complicated. Lots of things—cartilages, membranes, and ligaments—in a very small space. Use Figure 1.7 to see if it makes sense to you. We're going to offer a gloss on what's going on to make it a little easier to figure out. The cricoid cartilage is around the larynx. The thyroid cartilage is around everything, but only in the front. The cricoid cartilage stays in place because it's attached to the thyroid cartilage by the median cricothyroid ligaments at the thyroid angle and by the lateral cricothyroid ligaments on the sides. The ring that is the cricoid cartilage and the U-shaped thyroid cartilage are now firmly placed. The **arytenoids** (there are two of them, one on each side) sit just above the posterior of the cricoid cartilage, held to the cricoid cartilage by the cricoarytenoid ligament. The arytenoids are going to connect to the thyroid angle of the thyroid cartilage through two ligaments. One ligament is more superficial and medial than the other. They are the **vocal ligament** (on top) and the **vestibular ligament** (on the bottom).
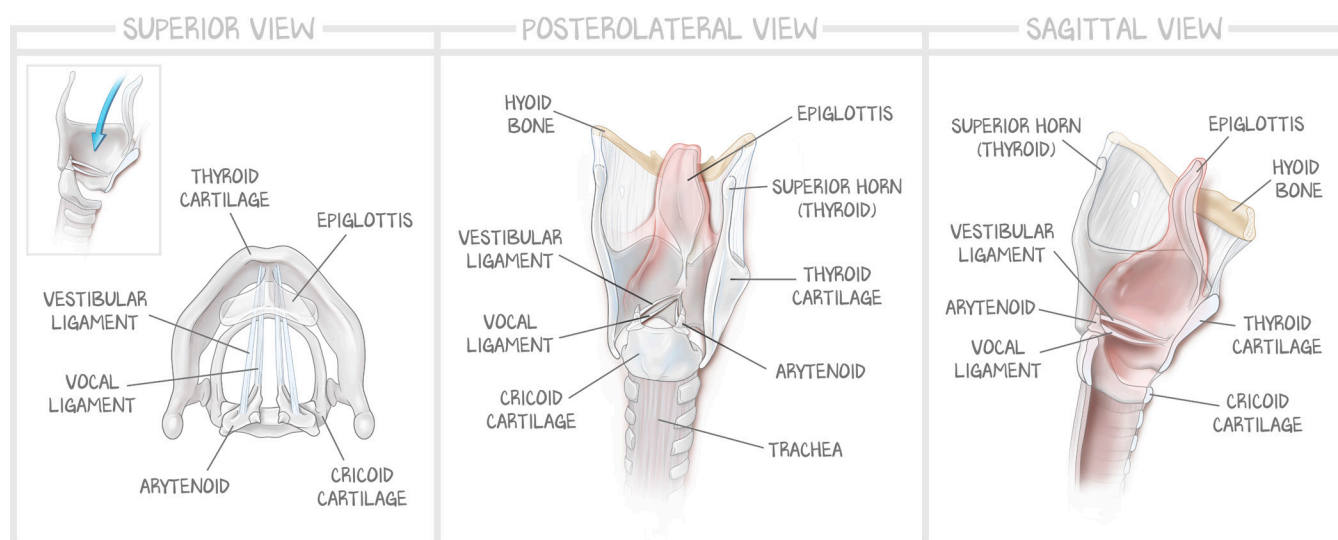

Figure 1.7: Larynx Anatomy
This figure serves as a visualization of the paragraph before it. We'll use this orienting anatomy to discuss the vocal folds, the vocal cords, next. Pay attention to the arytenoids and the orientation of the vestibular ligament and the vocal ligament.

The vocal ligament, vestibular ligament, and cricoid cartilage will serve as the "muscularis" for the oropharyngeal mucosa coming down from the epiglottis. As the mucosa comes down, it will first fold over the vestibular ligament, forming the **vestibular fold**. Then, adhering to the ligament, it will wrap under the ligament. It will reflect over itself, forming the **ventricle** as it starts over the top of the vocal ligament. As it passes over the vocal ligament, it wraps beneath it, forming the **vocal fold**. If we did not speak, if we had no vocal fold, there would be a transition from pharyngeal epithelium to respiratory epithelium at the epiglottis. Because humans can phonate, we need skeletal muscle and somatic control in the larynx. The vocal fold—pharyngeal epithelium overlying skeletal muscle— seems to be evolutionarily shoved into the respiratory epithelium. It makes it difficult to comprehend what's happening in the larynx, but we think it's worth the tradeoff for the ability to speak. Trying to communicate this in words is hard. Take a look at the next figure (Figure 1.8: Vocal Cord Epithelium Progression) and make sure this makes sense. If it doesn't, finish the video and then come back here.
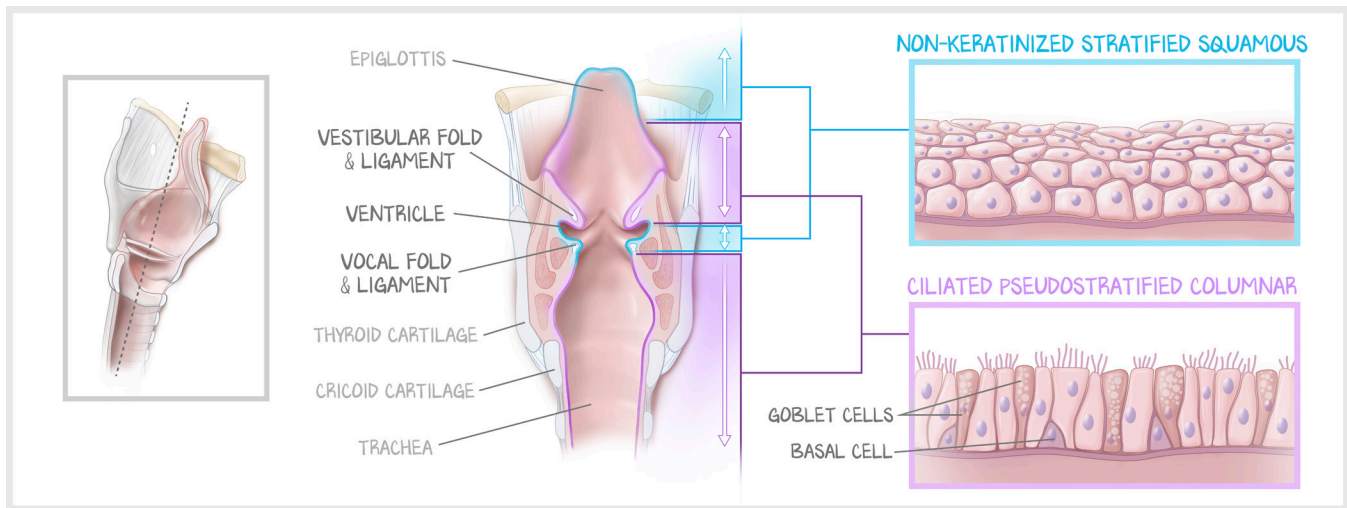
Figure 1.8: Vocal Cord Epithelium Progression
At the epiglottis, the stratified squamous epithelium of the oropharynx transitions to the respiratory epithelium of the airway. If there were no vocal cords, no vocal ligament, and no ventricle, there would be a simple transition from oropharyngeal epithelia to respiratory epithelia. Because we speak, the ventricle, vocal fold, and skeletal muscle are found as additional appendages just below the vestibular fold.

Think about what the epiglottis does during swallowing. It protects the trachea from the food bolus by closing over the opening to the trachea. Now think about it from the perspective of epithelia. When the epiglottis has closed off the trachea, as long as the person is upright, there are now top and bottom orientations. The epithelium on the bottom of the epiglottis is respiratory epithelium. And what is that side of the epiglottis covering? The trachea, which is also respiratory epithelium. Now the top of the epiglottis. It is lined with oropharyngeal epithelium—the same as the esophagus, nasopharynx, and oropharynx. Now open that epiglottis and take a breath. The 'top' is now anterior, and the 'bottom' is now posterior. The epithelial arrangements are designed to work when the epiglottis is closed.

The vocal cords add complexity by reintroducing oropharyngeal epithelium. The ventricle and the vocal cords are extra, added on to an immensely simple two-tube structure. This isn't profound if you've just been following along and totally get it. When we first came to this conclusion, it was mind-blowing.

The oropharyngeal side of the epiglottis is oropharyngeal mucosa. The trachea side of the epiglottis is respiratory epithelium. The trachea and bronchi are lined with respiratory epithelium. The vocal cords and the ventricle complicate things. On the **vocal fold** is where the **true vocal cords** are found. The vocal cords are lined with **esophageal mucosa**. In the **vestibular fold** is where the **false vocal cords** are found. The false vocal cords are lined with **respiratory mucosa**. The transition from esophageal to respiratory occurs **within the ventricle**.
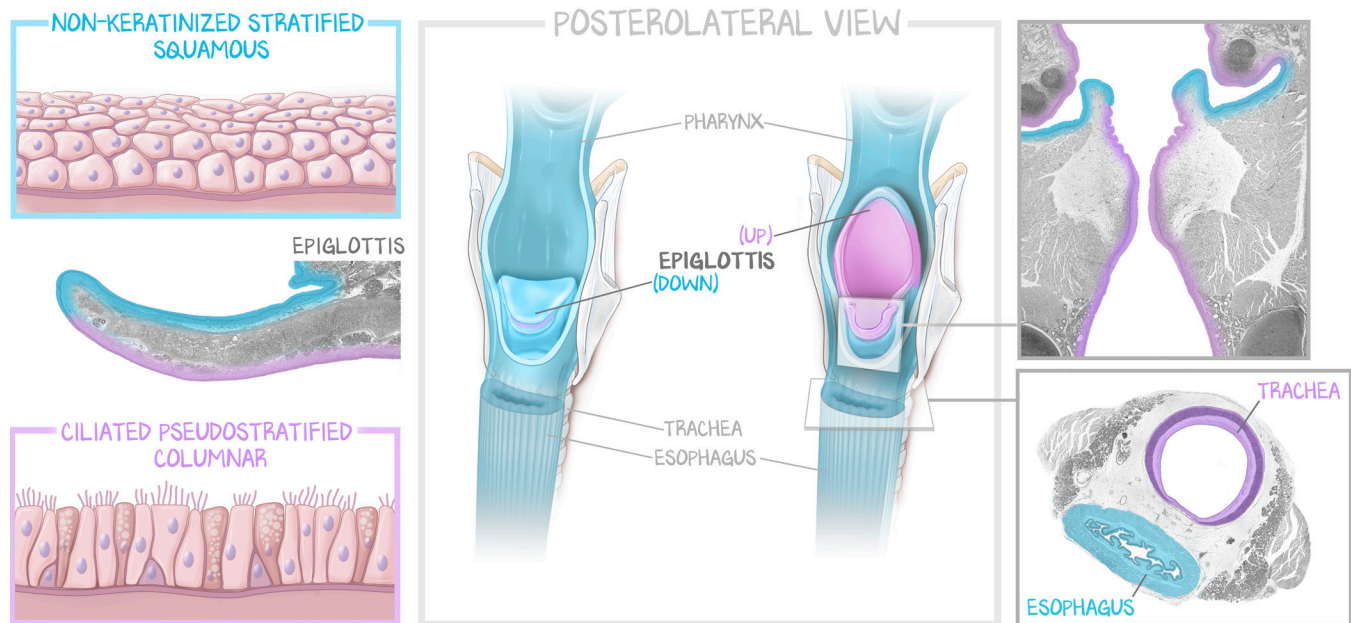
Figure 1.9: Histology of the Larynx
The vocal cords consist of stratified squamous epithelium with a basement membrane that separates the epithelium from a relatively loose connective tissue (hardly any cells in it). That connective tissue houses the vocalis muscle. The vestibular folds are respiratory epithelium with glands in the submucosa. The trachea, after the vocal fold, is also lined with respiratory epithelium with glands in the submucosa.

Practical ENT—Intubations

The way you will see the larynx is with the patient on their back, their head lifted into the sniff position, with a laryngoscope in your left hand and an endotracheal tube in your right. Explaining the anatomy this way isn't complete, but it is what you will need. The **arytenoid cartilages** are at the bottom of your view. They are little nubs that pop out at you. The vestibular ligament connects those arytenoids to the thyroid cartilage at the thyroid angle. The V-shaped space you see with epiglottis up, arytenoids down, and mucosa covering the vestibular fold is what you aim for when sliding the endotracheal tube into place.
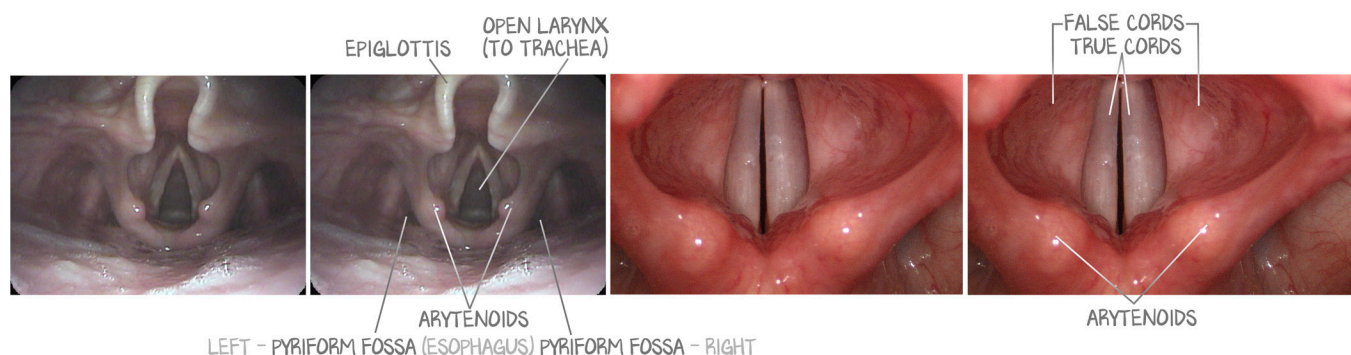

Figure 1.10: How You Will See the Larynx
Both of these were taken with video endoscopy, but have been inverted to show the position you will see while intubating a patient—epiglottis and the apex of the vocal cord triangle up. Right, a zoomed-out view of the structures with the vocal cord open (as in breathing) shows the surrounding anatomy. Left, a zoomed-in view of the structures with the vocal cords closed (as in swallowing or phonating) shows the false and true cords up close.